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Impact of adaptive devices on horses, assisting persons, and riders with cerebral palsy in a therapeutic riding program

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Hypothesis: The goal of this study was to evaluate the impact of three different adaptive devices used to facilitate therapeutic horseback riding for riders with cerebral palsy (CP), the horses, and the assisting persons. The study hypothesis was that there is no difference in clinical benefit to the rider; stress or physical saddle pressure to the horse; or the level of exertion required from assisting persons when using any of the three adaptive devices. Population: Individuals with varying disability due to cerebral palsy who participated in a therapeutic horseback riding program at a Professional Association of Therapeutic Horsemanship (PATH) Premier Accredited Center.

Intervention: Therapeutic horseback riding sessions using one of three adaptive devices. Comparators: Two commonly used adaptive devices (English saddle and bareback pad with backrider), and one recently developed, less-used device (Independence saddle). Outcomes: Clinical benefit for the individual with Cerebral Palsy was evaluated using an osteopathic musculoskeletal exam score. Equine stress was evaluated using a horse stress behavior ethogram. Physical pressure under the saddle of the horse was evaluated using a

Pliance Saddle pad under each adaptive device. Required level of exertion by assisting persons was measured using an assistant exertion score.

Conclusion: Therapeutic riding using an English saddle, a backriding pad with backrider, or an Independence saddle, by individuals with various degrees of disability, does not cause excessive stress or result in excessive pressure to the horse. Using one assistive device over another also does not appear to change the likelihood of clinical benefit to the rider. However, exertion scores for assisting persons were lower when the Independence saddle was used compared to the English saddle or backriding pad. Adaptive devices that allow an individual with

CP to improve function, ride more independently, provide some respite for the side walker and do not cause undue stress or frustration to the horse would be a great addition to the therapeutic regimen. Based on the results of this study, the Independence saddle is a viable alternative to the English saddle or the backriding pad for riders that would otherwise need extensive assisting person support in a therapeutic riding program.

Key words: cerebral palsy, therapeutic riding, equine behavior

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Therapeutic riding (TR) is an equine-assisted activity that aims to improve the mental and physical well-being of participants through the act of riding a horse. Equine assisted activities (EAA) have been used as an intervention for individuals with a broad range of physical and psychological issues (Engle BT & editor, 1997; Griffith JC, 1992; Huang X et al., 2006; All AC et al., 1999), and anecdotal evidence and case studies have heralded the positive effects of EAA for decades (Engle & editor, 1997; Mackinnon et al., 1995). Many studies have focused on individuals with specific physical handicaps, particularly cerebral palsy (CP) and multiple sclerosis (Bertoti, 1988; MacKay-Lyons et al., 1988) Early studies of EAA have been criticized for a lack of scientific rigor, small numbers of participants, lack of non-riding controls, and not including the most severely affected individuals (Sterba, 2007). However, with recent scientific interest in the interaction of humans and animals and the therapeutic role of animals, research teams are evaluating EAA for a variety of physical and psychological conditions in a more rigorous fashion. Despite the limitations, evidence suggests that TR and hippotherapy are efficacious, and may be medically indicated as therapy for gross motor rehabilitation for individuals with cerebral palsy (Engle & editor, 1997; Benda et al., 2003; Laiou et al., 2017; Mackinnon et al., 1995; Park et al., 2014; Snider et al., 2007).

The term cerebral palsy is used to describe a group of permanent movement and posture disorders that limit activity and are attributed to non-progressive insult to the fetal or infant brain (Rosenbaum et al., 2002). The Gross Motor Function Classification System is a method of grading the severity of impairment of people with cerebral palsy (https://www.canchild.ca/en/resources/42-gross-motor-function-classification-system-expandedrevised-gmfcs-e-r; Palisano et al., 1997; Palisano et al., 2000). Grades I and II include individuals who are able to walk without assistance, whereas those in Grades III–V have increasingly limited self-mobility. More severely affected individuals may lack strength in their core musculature and consequently have poor control of their trunk movements.

To obtain physical benefits of TR and to ride safely, riders with CP and other physical disabilities may require adaptive devices and several assisting persons. One adaptive device, the Independence Saddle™ (IS), was developed to allow a person with "severe physical challenges to sit safely and independently astride a horse, while the traditional physical dependency on side walkers is dramatically decreased" (http://www.independentstrides.com/saddle.htm). Additionally, the IS is a balanced saddle and may remove a source of stress and discomfort for the horse, since weight balance issues are a primary trigger for horse stress responses in this rider population (Foster & Wallach, 2015). Conversely, because of the increased size, bulk and mass of the IS when compared to traditional adaptive devices, the IS may be more stressful and aversive to the horse than other adaptive devices. The effect of the IS on the horse has not been investigated.

The goal of this study was to evaluate the impact of three different adaptive devices used to facilitate therapeutic horseback riding on the rider (an individual with cerebral palsy), the horse (a therapeutic riding horse), and the assisting persons. The study hypothesis was that there is no difference in clinical benefit to the rider, stress behaviors or physical saddle pressure to the horse, or the level of exertion required from assisting persons when using any of the three adaptive devices.

Methods

Riders

Ten individuals with CP, currently riding weekly, participated in this study (Table 1) at a Professional Association of Therapeutic Horsemanship International (PATH Intl. formerly NARHA) (http://www.pathintl.org) Premier Accredited Center. Inclusion criteria were: a diagnosis of CP; originally referred by a physician to the therapeutic riding program; currently participating in TR at CHUM; no ongoing medical conditions at the time of enrollment that might limit ability to participate (i.e. urinary tract infection, decubitus ulcers, chronic respiratory disease); and parents/guardians willing to be involved in extra rides for saddle pressure measurements that would require additional travel to CHUM. Individuals with CP meeting these criteria that had not been participating in the TR program at CHUM for at least one year were excluded from the study. The goal of the original physician referral to CHUM for TR was to improve functional mobility, including stamina, strength, balance, coordination, and core strength. Because these participants were riders in an existing program, they were able to continue riding on their usual schedule, i.e. the evaluation was scheduled around the riders' schedule to minimize differences in the study intervention and typical TR sessions. Most riders had spastic paresis and were severely disabled (Table 1). While some participants are capable of performing select functions of independent living, none of the participants in the study were capable of independent living.

The family (or caregiver) burden in the current study is notable. In order to participate, 6 of 10 riders needed a special van with a lift for transportation. Families traveled at least 70 minutes, and up to >5 hours (round trip), not including entry and exit in to the vehicle, to participate. For example, one rider lived in a group home, so to participate, a parent drove from home to the group home, to CHUM, and then back, with travel time exceeding 3 hours per visit. Another rider had 8 additional siblings with significant special needs in the family. If a caretaker was not available, all 9 individuals had to be loaded into a vehicle and taken to CHUM for one rider to participate.

Table 1. General characteristics of riders.

ID	Age (Yr)	Gender	Weight (kg) / Height (in)	Motor Classification /GMFCS	Topographical Classification	Able to Ambulate	Verbal	Independent (life)	Years riding
5	18	M	55/54	Spastic / III	Paraplegic	With Lofstrand crutches	Yes	Yes	15
6	21	M	54/54	Spastic / V	Quadriplegic	No, wheelchair	No	No	17
7	2	F	12/37	Spastic / V	Quadriplegic	No	No	No	2
8	9	F	21/48	Spastic / V	Quadriplegic	No	No	No	5
9	20	F	59/66	Spastic / II	Hemiplegic	Yes, with orthotics	Yes	Yes	10
10	16	M	60/66	Spastic / II	Quadriplegic	Yes, with orthotics	Yes	Yes	16
11	8	F	27/60	Athetoid / V	Quadriplegic	Power chair ambulatory	Yes	No	10
12	28	M	34/48	Spastic / V	Quadriplegic	No	No	No	15
13	13	F	28/48	Spastic / V	Quadriplegic	Power chair ambulatory	Yes	No	6
14	24	M	47/66	Spastic / V	Quadriplegic	Power chair ambulatory	Yes	No	15

Characteristics of the individuals with cerebral palsy who participated in the study. All riders were already involved in therapeutic riding and rode weekly. A physician had referred riders to the program. The goal of referral was to improve functional mobility. Age, height, weight, and years riding were determined at the beginning of the study. Motor and topographical classification, ability to ambulate, verbal category (yes/no) and ability to perform activities of daily living (independent) were determined by medical care provider. GMFCS = Gross Motor Function Classification System for cerebral palsy, with I = minimal impairment in mobility and V = severe impairment in mobility (Palisamo et al 1997). Participants were currently riding in a therapeutic riding program one time per week, and one of the indications for the sessions was to improve core strength. Orthotics = custom external braces (http://www.cerebralpalsy.org/information/mobility/orthotics). Power chair = wheel chair operated by the individual with cerebral palsy (or care giver) using a joystick.

Horses

Six horses participated in this study (Table 2). This study did not involve any activities other than those that the horses routinely performed in their role in equine assisted activities and therapies. In compliance with PATH guidelines, horses were not ridden more than three hours per 12-hour day and not ridden more than four days per week. The size, gait, temperament, height, and body width determine if a horse is suited for an adaptive device. For example, a bareback pad (BP) with backrider is more appropriate on a horse of

1100 pounds than a 900-pound horse. To match the rider and device, PATH Certified Instructors follow PATH safety guideline and use their knowledge of horsemanship to make decisions regarding horserider-adaptive devices combinations. In the current study, the PATH certified instructor made all rider-horse decisions in the absence if input or intentional influence by riders, parents/guardians, or researchers. The study closely mimicked the conditions in a working therapeutic riding program. Of the six horses in the study, four horses were ridden in the English saddle (ES); three horses in BP; and three horses with the IS. One of the six horses in the study was ridden with all three adaptive devices (ES, BP, IS); two were ridden with two devices (IS and ES); and three with one adaptive device (BP = 2; ES = 1; Table 2).

Table 2: Characteristics of horses

				Equine activities					
Horse	Age, yrs	Breed	Years in program	TR	HPOT	Sport / recreation	4H	Trails / camping	Parades / demos
1	12	Spanish mustang	4	X (ES, IS)	X	X	X	X	X
2	4	QH	1	X (ES, IS)		X	X	X	X
3	7	Draft X QH	2	X (BP)	X	X	X	X	
4	12	Saddlebred	10	X (ES, BP, IS)	X	X	X	X	X
5	4	Mustang X QH	2	X (ES)		X	X	X	
6	7	QH	5	X (BP)	X	X	X	X	X

The project was approved by Michigan State University Institutional Review Board (IRB#03-047) and explained to the individual and his/her parent /guardian. Informed written consent was obtained from all parents/guardians and assent from riders. The project was exempt from filing an Institutional Animal Care and Use Committee Animal Use Form. The exemption was approved because the horses were kept under generally accepted agricultural management practices and the research involved only observation of the horses doing their usual job.

Program

Riding and evaluation took place at CHUM (Children and Horses United in Movement) Therapeutic Riding, Dansville, Michigan (Kaiser et al., 2006a). CHUM is a Premier Accredited Center by Professional Association of Therapeutic Horsemanship International and is run as a 501C3. The facility is 35 acres, and includes a barn with horse stalls and hay storage, pasture, an indoor heated arena (66 x 128 ft.), outdoor riding ring (80 x 160 ft.), and trails. Horses have 24/7 access to pasture and run in stalls and hay, and are fed concentrate indoors twice daily. Twelve horses are housed at the facility, and participate in various therapeutic riding and lesson riding activities as well as in hippotherapy. Six horses participated in this study. Routine veterinary care, hoof trimming, dental care, chiropractic manipulation, acupuncture, and massage were provided as needed.

Evaluation of the rider, horse behavior (except behavior at pasture), and side walker exertion was done in the indoor arena. Part of the horse management protocol is that all riders mount from a 4 x 8 platform. The platform is accessed by a built-in ramp and can accommodate caregivers who carry riders, wheel chairs, riders with crutches, and independent riders. The horse stands facing the arena while the rider mounts from the platform.

Rider evaluation

Osteopathic musculoskeletal examination (OME): We used the OME of the Hospitalized Patient Form to clinically evaluate the rider before and after riding. The OME is the standard to determine areas requiring osteopathic manipulation, to assess the effectiveness of manipulation, and evaluates symmetry/asymmetry, range of motion restriction, texture of the skin, and tone of the skeletal muscles in various regions of the spine, pelvis and the rib cage (Sleszynski et al., 2004). The OME was completed by the same osteopathic physician (SG), and a clinical comparison made between the before and after riding OME. Categories of the assessment were clinically improved, no change, or clinically worse. The frequency of riders experiencing clinical improvement, no change, or clinical worsening was compared using the Pearson's Chi Squares test except in cases where any category had less than 5 observations. In this situation, Fisher's Exact test was used to make the comparison.

Riding Protocols

Two different riding protocols were used in this study: a therapeutic riding lesson riding protocol and a pressure pad protocol.

Therapeutic riding lesson riding protocol. For behavioral assessment of the horses, assistant exertion, and osteopathic medicine evaluation, riding was scheduled for one hour, one time per week. To reduce the burden of participation on the rider and their caregivers, riding lessons that were a part of this study were scheduled on the day of the week and at the time of day the rider typically participated in a riding lesson. Equine behavior, side walker exertion, and OME data were obtained for the three different adaptive devices: ES, BP, and the IS. Each rider rode one time on each device. On occasion, due to the riders' schedule, two riders rode on different horses using different devices during the same lesson time. When this occurred two observers were available to assess behavior and videotape each horse-rider combination. The therapeutic riding lesson protocol was scheduled for weekly rides over a 12-week period. Because individuals with cerebral palsy are at risk for developing infections and other medical complications, make-up rides for this protocol were scheduled at the caregivers' convenience. All rides were completed within an eight-month time frame.

The therapeutic riding lesson was approximately one hour in length with approximately 30 minutes of functional riding activity. Riders with severe disability require additional time and staff to mount the horse. Riders mounted the horse with stand-by assist (n=3); two person standing pivot (n=2); and total lift (n=5). Riding activities included, with the horse at the walk, weaving through cones, circling barrels, walking over poles on the ground, halt walk transitions, and upper extremity play. Activities were carried out moving in both a clockwise and counterclockwise direction.

Pressure pad protocol. Because of the complexity associated with saddle pressure measurements involving riders with physical disabilities, core strength, and balance issues, and because the equipment was used during the week at the university, pressure measurements were scheduled separately from the therapeutic riding lesson protocol and took place on weekends. Extra time was given to accommodate the needs of each rider. To measure saddle pressure, the rider had to be able to ride without any assistance for four minutes. Saddle pressure was measured for one rider, on one horse, with one device at a time. Pressure recordings were made for each rider on each device. One rider-device combination was recorded per day and there was a minimum of seven days between pressure recording sessions.

Riders with limited core strength and serious balance issues were unable to complete the entire saddle pressure protocol for some devices. Due to issues of rider fatigue, imbalance and limited core strength, as well as repeated technical issues with the Pliance system, data were not recorded for all riders on all devices. Ultimately pressure data were obtained from eight riders on the ES, five on the BP; and four on the IS.

When technical difficulties occurred, make up rides were scheduled at the parent/guardians' convenience; however, health issues of the riders, financial constraints, and caregiver illness/death made it impossible to schedule make up rides within a reasonable period.

For the pressure pad protocol, each device was evaluated using the same pattern of riding, consisting of a series of straights and turns moving in both clockwise and counterclockwise directions at the walk.

Adaptive Devices

Therapeutic riding utilizes a number of adaptive devices and practices to enable individuals with physical disabilities to ride.

Traditional adaptive devices include the conventional English style dressage or hunt seat saddle and the backriding pad. In this study the BP was only used with a backrider.

English saddle. The ES provides minimal medio-lateral (ML) or anterior-posterior (AP) support for the rider. Riding independently in this saddle requires sufficient core strength, balance, and the ability to adduct and stretch the legs over the sides of the horse and into the stirrups. With this saddle, individuals with insufficient core strength, and those unable to ride independently, require side walkers. Side walkers must have sufficient strength and height to provide both ML and AP support to the rider, while walking along the side of the horse (Figure 1). We have previously shown that riders with cerebral palsy have significantly greater anterior-posterior and medio-lateral range of motion in the ES when compared to able-bodied riders (Clayton et al., 2011). The ES is positioned on the horse in the cranial and mid thoracic spine. Use of the ES for individuals with extremely poor balance or uncontrolled athetoid movements, raises concern for the welfare of the horse. Sudden and unexpected movements of the rider may cause a startle response, or result in abnormal pressure, pain, or imbalance to the horse. The ES used in this study weighed 5.6 kg (with pad), was 22 in wide (from bottom of stirrup flap to bottom of stirrup flap), 17 in long (front to back), with a maximum height in the rear of 3.5 in.

Figure 1. Adaptive Devices In Use. A. Rider and assisting persons using the English saddle (ES). B. Rider, backrider, and assisting persons using the backriding pad (BP). C. Rider and assisting persons using the Independence saddle (IS). Note that with the ES the side walkers have both hands on the rider to maintain balance and safety (A.). With the BP and IS (B. and C.) side walkers are not touching the rider. The ES weighed 5.6 kg (with pad), was 22 in wide (from bottom of stirrup flap to bottom of stirrup flap), 17 in long (front to back), with a maximum height in the rear of 3.5 in. The BP and blankets weighed 8.2 kg, was 15 in wide, 17 in long, with a maximum height in the rear of 1 in. The total weight of the BP and back rider was 97.6 kg. The IS weighed 30.1 kg, was 26 in wide, 22 in long, with a maximum height in the rear of 18 in.

Backriding pad. Backriding involves the use of the backriding pad (BP; also referred to as a bareback pad) with the rider sitting in front of a trained individual (the backrider) who must have sufficient strength and balance to provide both ML and AP support for the rider (Figure 1). The horse is fitted with a saddle pad and backriding pad. The backrider generally supplies support for the rider, and the side walkers generally provide little or no physical support for the rider. The BP is very useful for young or extremely small individuals, where the total weight of both the rider and the backrider is not greater than one larger adult. However, using the BP may cause welfare issues for the horse not only because the horse may be carrying more weight, but also because of how the weight is distributed. With the BP, most of the weight is carried farther back over the horse's caudal thoracic and lumbar spine, which is less well supported than the cranial mid thoracic spine. Furthermore, the different movements of the two riders during backriding could be stressful to the horse. Backriding is not appropriate for full sized adults, regardless of the level of disability. It is typically recommended that a horse not carry more that 20-25% of its body weight (Powell DM et al., 2008); thus a 1000-pound horse would be expected to safely carry less than 250 pounds of rider(s) and equipment. The estimated weight of two full sized adults is between 370 and 400 pounds (http://www.cdc.gov/nchs/fastats/bodymeasurements.htm) and would require a large horse, weighing 1500 pounds or more. The backriding pad and blankets used in this study weighed 8.2 kg, were 15 in wide (from bottom of stirrup flap to bottom of stirrup flap), 17 in long (front to back), with a maximum height in the rear of 1 in. The total weight of the backriding pad and backrider (instructor) was 97.6 kg.

The Independence Saddle. This is a recently developed adaptive device with adjustable and removable headrest, backrest, forearm supports, handgrips, quick-release safety stirrups, and a safety release system (Figure 1). With the IS, severely disabled individuals are able to sit independently in the saddle. The parts of this saddle that support the rider are fully adjustable and can be configured or removed in accordance with the individual rider's needs. When using the IS, the horse is led and side walkers may be required to assist in repositioning individuals with poor core strength or athetoid upper body movements. Although the IS may provide a disabled individual the ability to ride with minimal assistance, there are potential equine welfare concerns with this device. The IS is longer, heavier, more rigid, and more upright than conventional English or Western saddles, potentially resulting in increased total weight or abnormally distributed weight and pressure. The IS may also affect the horse's balance. Neither the physical nor the psychological effects on the horse have been investigated previously.

The IS used in this study weighed 30.1 kg (saddle = 16.4; arms and back = 9.5; wool pad = 4.2 kg; the head rest was not used). The IS was 26 in wide (from bottom of stirrup flap to bottom of stirrup flap), 22 in long (front to back), with a maximum height in the rear of 18 in (without the head rest).

Evaluation of Equine Behavior

Certain equine behaviors are associated with stress in the horse, and observation of these behaviors can be a useful way to assess if horses perceive various activities as stressful (Heleski et al., 2009; Kaiser et al., 2006a). We have developed a tool (equine ethogram, Table 3) for evaluating the behavior of the horse under different conditions, including therapeutic riding (Kaiser et al., 2006a). We use the word "stress" to include behaviors indicating conflict, frustration, or irritation.

Table 3. Horse behavior ethogram

Behavior	Descriptions
Head toss	horse moves head quickly out of "neutral" position (i.e. where it is positioned the majority of the ride); oscillation; will contain some movement in medial-lateral plane
Head raised	head held higher than the normal carriage with nose extended upward and with slight extension of the neck
Head down	head held lower than the normal carriage, neck may be stretched out with nose pushed forward
Head shake	movement in vertical plane dorsally or ventrally; might be only nose
Head turn	lateral cervical flexion not in line with rest of horse's body; horse may appear to be making a threat display toward one of handlers
Head tilt	nasal midline not perpendicular to ground; deviation of angle of nasal midline to left or right
Ears pinned back	ears pressed caudally against the poll area of the neck

Tail Lash/Tail swish	dorsa-ventral movement of caudal vertebrae; movement of tail beyond that of simple rhythmic swaying of the tail; and/or circular (or medial-lateral) movement of caudal vertebrae

**Other behaviors representing conflict/frustration/irritation such as frequent defecation, baring of teeth, kicking, striking, rearing or bucking were never observed in this population. We did not record chomping of the bit because most horses were not ridden with bits.

Ethogram of stress (conflict/frustration/irritation) behaviors observed in horses while being ridden in a therapeutic riding program (Kaiser et al. 2006). The ethogram represents behaviors previous identified in a therapeutic riding and research setting. We did not observe the following behaviors and they were not included in the ethogram: arched neck threat; ears laid back /threat; snapping; bite threat or bite; strike threat or strike; kick threat or kick. Frequent defecation, baring of teeth, kicking, striking, rearing or bucking were never observed in this population. Most horses were not ridden with a bit, so bit chomping was not included in the ethogram.

Sessions were both live assessed and video recorded. Video recording was used for later assessment and to calculate inter observer reliability. Two observers were trained to assess the behaviors based on the ethogram. Due to the nature of the adaptive devices, blinded behavioral assessment was not possible.

Fifty-five therapeutic riding sessions were observed to assess stress behaviors of the horses ridden under three different conditions (ES, n= 21; BP, n= 14; IS, n=20). Behavior was assessed from all riders during the therapeutic riding lesson protocol with the following observation protocol: behaviors during mounting and dismounting were observed (average of 3 minutes data), along with the following time points: 0-1 min of the riding session, 5-6 min, 10-11 min, 15-16 min, 20-21 min, and 25-26 min, thus approximately 9 min of behavioral data were collected for each riding session. Behavior was also assessed during the saddle pad pressure protocol during mounting and dismounting and each time saddle pressure was recorded. Saddle pressure was recorded three times when the horse was at the walk going straight. The total observation data for horse behavior was 495 minutes of data. Due to the constraints of conducting this research in an ongoing therapeutic riding program, we did not have the identical number of trials per rider, per horse, or per condition. To determine that horses were capable of exhibiting stress behaviors, behavior was additionally assessed on the same horses used in this study during four traditional lessons (using the therapeutic riding lesson protocol) and over a four-hour period (using the assisting persons protocol; one minute of observation every five minutes) when the same horses were at pasture.

To determine the number of individuals required to detect statistically significant differences, we performed power analysis for equine behavior and side walker exertion. Using equine behavior as an example, we used a model that included the effect of treatment (saddle), but also the effect of rider, since this factor is an important source of variation in our study. This requires data from each rider in all treatments. Power analysis showed that with 30 samples (i.e., 10 riders who each ride in the three different adaptive devices) we have a power near 0.99 (99% probability to find differences between treatments). With only 3 samples in each treatment (9 samples total) we have a power of 0.86. (Power analysis was conducted by the MSU College of Agriculture and Natural Resources Statistical Consulting Center). Similar numbers were obtained when statistical power was determined using preliminary data for side walker exertion.

Measurement of Saddle Pressure

Force and pressure measurement. A thin elastic electronic pressure mat (Pliance Saddle System, Novel GmbH, Germany) was used to measure the pressure distribution between the adaptive device and the horse, as previously described (Clayton et al., 2011; de Cocq et al., 2009). The mat consists of two distinct sides measuring 512 mm x 570 mm (each of which has 128 sensors arranged in 8 columns and 16 rows), that measure pressure applied perpendicular to their surface.

The pressure mat was calibrated in a pneumatic calibration frame prior to the start of data collection. The pressure mat was placed in a similar location on each horse and the sensors on the mat were zeroed to match the contour of the horse's back. The appropriate adaptive device was then placed on top of the mat. The girth was tightened gradually to the preferred length. The rider was then assisted, as needed, to mount the horse from a high platform, and any necessary adjustments to the tack were made.

Saddle pressure was measured for one rider, on one horse, with one device at a time. For riders with physical disabilities, set up time for each pressure measurement could take up to 15 minutes. For each rider, three 10-second pressure recordings were made at a sampling frequency of 60 Hz as the horse walked on a straight line. If a rider became obviously unbalanced or was assisted, pressure recordings during that period were discarded. Three trials per rider per device were obtained and analyzed. Pressure recordings were made for each rider on each device. One rider-device combination was recorded per day and there was a minimum of seven days between pressure recording sessions.

Each trial was analyzed using proprietary (Novel Electronics) and custom software (Matlab, Mathworks). The force on each sensor was calculated by multiplying the pressure (kPa) by the sensor's area (9.375 cm^2). To analyze the results, the area of the saddle pad was subdivided into left and right halves, and each half further subdivided into front, middle, and back thirds.

This allowed an evaluation of weight distribution on different areas of the horse's back. Because of the number of variables (horse, device, riders), and the low number of riders per device with useful data, we were unable to make meaningful statistical comparisons between adaptive devices in regards to saddle pad pressure.

Assistant exertion. Therapeutic riding for individuals with physical disabilities can require a great deal of physical effort on the part of the side walkers, most of whom are volunteers. The backrider may also require a great deal of physical strength to hold the rider in the appropriate position, Thus, adaptive devices that would not only improve the quality of the ride for the rider, but also decrease the physical work of the volunteers, assistants and staff could be useful. An exertion scoring scale (Table 4) was developed for side walkers and the backrider. Exertion was rated on a scale of 0 to 3; with 0 representing no assistance given to the rider and 3 representing high degree of assistance, i.e., the side walker must work to keep rider in the saddle. Total assistance score was acquired by combining exertion scores of all volunteers involved; this included one or two side walkers and the backrider when applicable. Exertion data were assessed live as well as from video recordings. Exertion was assessed three different conditions for approximately one minute every five minutes during therapeutic riding lesson protocol (ES, n= 7; BP, n= 4; IS, n=7).

Results

Outcome 1 Clinical Benefit for the Individual with CP

Pre and post OME evaluations were done for all participants, for all rides, on all devices (n=30). Without considering the particular adaptive device used, almost two-thirds (19/30, 63%) of riding lessons resulted in clinical improvement after a riding lesson compared to before a ridin g lesson. Six individuals were clinically worse and there was no change in five when pre/post OME evaluations were compared. Looking specifically at OME data from each individual with CP after using the device chosen by the therapist, almost two-thirds (6/10, 60%) showed clinical improvement after riding in their usual adaptive device chosen by the PATH Certified instructor, two showed no change, and two were clinically worse (Table 5). There was no difference in the frequency of riders in each of these categories when using either of the other two devices not chosen by the instructor (13/20 with clinical improvement, 4/20 with clinical decline, and 3/20 with no change; p>0.9). Furthermore, there was no difference in the frequency of riders who were clinically improved, the same, or clinically better when comparing IS to ES, IS to BP, and ES to BP (data not shown).

Table 4. Assistant exertion scale

Score	Description
0	Assistance not needed; side walker not needed; walked next to rider as a safety precaution, but no assistance given
1	Minimal assistance; side walkers arms generally at sides, with brief assist
2	Medium assistance; side walkers or back rider provides light support, or supports with only one hand
3	High support; side walker or back rider must work to keep rider in saddle, both hands used

For the safety of the horse and rider, and to enable individuals with handicaps to obtain the physical and psychological benefit of the motion of the horse, side walkers walk along the side of the horse when being ridden by riders that need assistance. Side walkers provide anterior-posterior and medial-lateral support for riders with poor core strength, balance, and coordination. Side walkers were present at all times when the riders rode with the three adaptive devices. The scale ranges from a minimum of 0 (no support needed or provided) to a maximum of 3 (support of the rider required by side walkers throughout the entire ride).

Outcome 2 Stress and pressure on the Horse

Stress behaviors were evaluated from 55 TR riding sessions; a total of 495 minutes of data. An average of 3.2 stress behaviors per session were observed in sessions using the IS (n=20), compared to 1.7 stress behaviors per session using the ES (n=21) and 3.6 stress behaviors per session when using BP (n=20) demonstrating no difference in stress behaviors between the three devices. For comparison, the frequency of stress behaviors demonstrated by these horses in a pasture setting was 5.2 stress behaviors per session. However, stress behaviors were more frequent during traditional lessons (12.4 stress behaviors per session) than any of the other conditions ($P < 0.02$).

Kilopascal is the unit of pressure that is measured by the Pliance pressure mat; force (newtons) is calculated by multiplying pressure by area; and in turn the weight of the subject and device is used when calculating mass normalized force (N/kg). Average rider weight (kg) for each device was: 35.2±16.8 (ES); 28.3±16.0 (BP); and 41.8±12.3 (IS). Device weight (kg) was 5.6 (ES); 89.4 (BP); and 30.1 (IS). Note the BP weight included the weight of the device and the backrider.

Table 5. OME clinical evaluation

ID	ES	BP	IS
5	-	+	+
6	+	-	+
7	-	+	+
8	nc	+	-
9	+	+	+
10	+	+	-
11	-	+	nc
12	+	+	+
13	nc	nc	+
14	+	+	nc

Comparison of OME results after riding to results obtained before riding for the three different adaptive devices; ES = English saddle; BP = backriding pad (with backrider); IS = Independence saddle. Clinical evaluation assessed as improved (+), no change (nc) or clinically worse (-). Bold red indicates the adaptive device chosen by the PATH certified instructor that the rider usually used when riding. There was no difference in the frequency of patients who did or did not show clinical improvement whether comparing use of one device to another or comparing those who were using the device recommended by the therapist, versus any other device (data not shown).

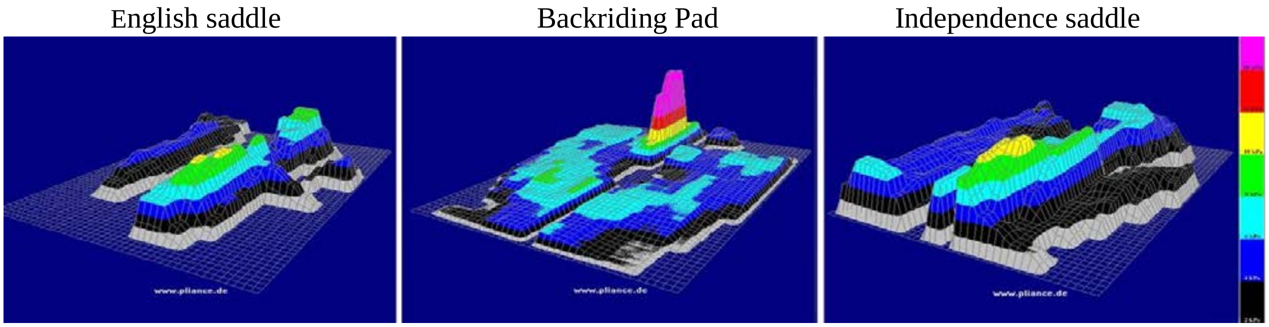

Figure 2: Representative three-dimensional pressure scans at the point of maximal total force for the English saddle (ES, left), backriding pad (BP, center), and Independence saddle (IS, right) for the same rider. The front of the saddle is at the top of the scans. Pressure exerted on each sensor is color-coded based on the pressure scale (right), with black indicating the lowest and bright pink being the highest pressure measured. Scans are a good representative of the pressure for each device and illustrate the differences in the magnitude and distribution of pressure between devices. The high pressure on the BP scan represents the girth area of the backriding pad. This area of high pressure is also observed with the backriding pad without a rider (data not shown).

Figure 2 shows three-dimensional pressure scans at the point of maximal total force for the ES (left), BP (center), and IS (right) for the same rider (Rider # 11). The front of the saddle is at the top of the scans. Overall, the maximal total force with any of the adaptive devices used in this study is not excessive, though use of the BP shows areas of higher pressure near the withers underneath the girthing system. This area of higher pressure was consistently seen with the BP, but not with other adaptive devices. No physical trauma or lesions were observed on the horse with any of the devices.

Table 6: Force and pressure variables for the English saddle (ES), back riding (BP), and Independence saddle (IS)

	English saddle	Backriding	Independence saddle
Total force (N)	400±133.72	974±83.49	723±170.25
Mass normalized force (N/kg)	10.3±2.3	7.8±0.5	10.1±1.5
Maximal Pressure on any sensor (kPa)	28.75	63.75	28.00
Average number of sensors measuring pressure >40 kPa	0±0	148±65	0±0
Average Pressure (kPa)	4.65±0.75	5.41±0.20	4.60±0.37
Left front (kPa)	4.54±0.68	6.18±0.33	4.71±1.15
Right front (kPa)	4.27±0.60	4.42±0.25	4.72±0.20
Left middle (kPa)	4.47±0.77	5.74±0.52	4.15±0.44
Right middle (kPa)	4.45±0.70	4.37±0.87	4.25±0.53
Left rear (kPa)	4.59±1.74	6.08±0.66	4.87±0.38
Right rear (kPa)	4.94±1.64	5.29±0.77	5.02±0.13

Mean values (±SD) for force and pressure variables measured under the ES (n= 8 riders), BP (n=5), and IS (n=4). The table shows force in Newtons and pressure in kilopascals. Kilopascal is a unit of pressure measurement that has widely replaced pounds per square inch. For comparison the total force for a rider using a dressage saddle was 843 Newtons and a treeless saddle was 794 Newtons (Belock B et al., 2012). The force is also normalized for the weight of the rider and assisting devices (Mass normalized force (N/kg). The maximum pressure on any sensor refers to the highest pressure reading obtained during recording. For comparison the maximal pressure on any sensor was 20.7kPa (Belock B et al., 2012). The pressure for the right and left sides and front, middle, and back were also recorded. The high pressure in the left front in back riding corresponds to the area where the pad was girthed. The average number of sensors measuring > 20, 40, and 60 KPa was evaluated, and back riding had more sensors measuring > 40 KPa of pressure.

Table 6 shows average force and pressure variables for the three adaptive devices. Backriding showed higher pressures overall, some of which is related to the girthing system.

Outcome 3 Required Level of Exertion by Assisting Persons

Assistant exertion was assessed for the ES (n=7); BP (n=4); and IS (n=7) for approximately one minute every five minutes during therapeutic riding lesson protocol. The average exertion scores while using the IS (1.2+/-0.28) were significantly lower ($p<0.0025$) when compared to ES (2.1+/-0.25) or BP (3.7+/-0.64).

Discussion

Adaptive devices that allow an individual with CP to improve function, ride more independently, provide some respite for the assisting persons, and not cause undue stress or frustration to the horse would be a great addition to the therapeutic regimen. Families with children with CP often lead complicated lives (http://www.cerebralpalsy.org/about-cerebral-palsy/definition). They have to manage more doctor appointments, more therapy sessions, and more physical accommodations/equipment than most parents with typically developing children. Participating in a study that puts addition demands on the family is often a hard sell if the study is science for the sake of science. However, the fact that families were willing to participate in the current study and take on the added demands as a result suggests that they believe in TR and that it has value as part of their child's therapy. An often-overlooked threat to therapeutic riding programs like CHUM offering therapeutic riding to children with CP is the availability of assisting persons, who are generally volunteers or family members. Without these team members, the capacity of a program to serve children with CP is dramatically reduced. Considering that clinical outcomes for the rider and stress behaviors for the horse were similar using the Independence Saddle compared to either of the other devices, the Independence Saddle should be considered a viable option that may incentivize the assisting person(s) with a lighter workload.

Cerebral palsy is a chronic incurable condition that requires ongoing life-long treatment and therapy that is uniquely tailored to the individual (http://www.cerebralpalsy.org/about-cerebralpalsy/definition). The goal of the treatment plan is to utilize different therapies to maintain and promotes mobility and function. Based on the OME, clinical improvement was observed after the majority of riding lessons (63%). No single device had a higher likelihood of improving clinical outcomes than any other in this study. While these results suggest that the PATH certified therapist could make horse assignments solely of the basis of safety of the rider and temperament of the horse, it is recognized that this conclusion is based on a single modality for assessing clinical outcome. The OME is a recognized clinical outcome that is appropriate for assessing improvement after TR. In this study one doctor of osteopathic medicine (SG) an osteopathic manipulation specialist assessed each rider before and after each ride on each device. However, additional clinical outcome measures, and patient/family reported outcomes measures should be considered for future work.

This study found no difference in the average number of stress behaviors, suggesting that when compared to other adaptive devices, the IS does not result in more stress behaviors in the horse. Further, these data support our earlier work showing that therapeutic riding, at least at this center, with this set of horses, is not perceived by the horses as being mentally stressful (Figure 3). Horses did not perceive one adaptive device as more aversive than another. In addition, horses in this study did not show significantly more stress behaviors than when they were ridden in traditional lessons.

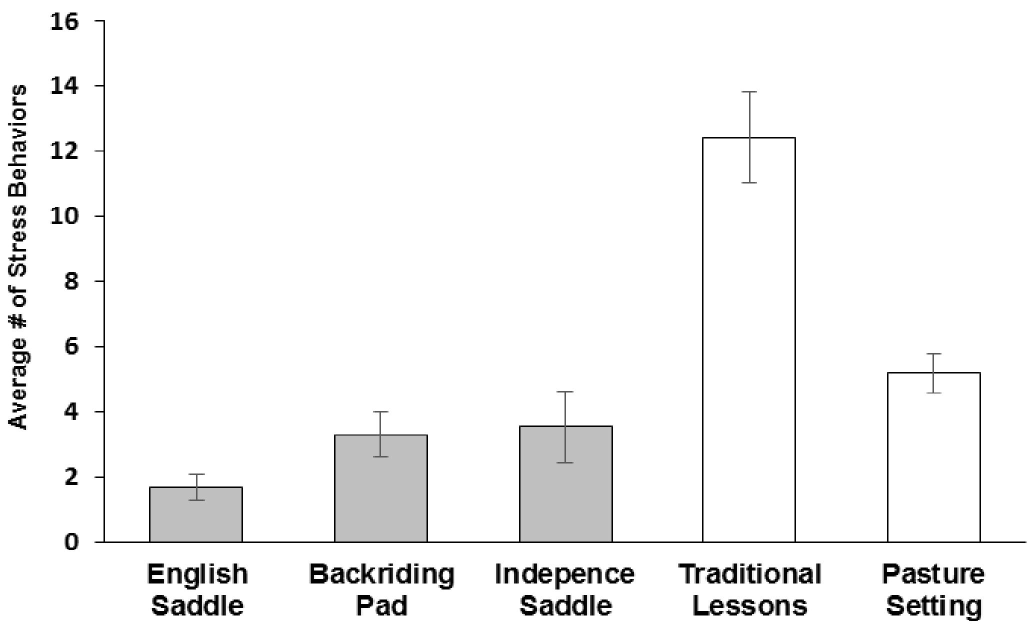

Figure 3. Stress (conflict/frustration/irritation) behaviors exhibited by horses when ridden with three adaptive devices and comparing with traditional lessons and pasture setting. Stress behaviors were evaluated from 55 riding session as well as traditional lessons being ridden by the horses in this study. In addition stress behaviors were evaluated with the horses in a pasture setting. Stress behaviors were more prevalent during traditional lessons than any of the other conditions ($P = 0.02$). Error bars represent standard error of the mean (SEM).

We have previously shown that horses in a therapeutic riding program show low levels of stress behaviors, but these levels increase when the same horses are ridden in a horse show (Kaiser et al., 2006a). Taken together these studies suggest that therapeutic riding with multiple adaptations and with individuals with various degrees of disability is not necessarily stressful to the horse when equine temperament, physical ability, and rider's needs are correctly matched. It should be noted that stress behaviors in all situations were low.

Our results are in agreement with another study that found no difference in salivary cortisol (used to assess stress) in therapeutic riding horses ridden in a hunt seat saddle (a specific English saddle) by children at a riding camp or by children with emotional issues, compared to horses at rest (McKinney et al., 2015). Using our equine ethogram (Kaiser et al., 2006a) to assess behavior, they also measured salivary cortisol three times per week over six weeks. To eliminate circadian changes in cortisol, samples were obtained at the same time, after mounting (3 PM), after riding (3:30 PM), and after one hour of riding (4 PM). Similar to our study, horses exhibited few stress behaviors. There was no significant difference in delta cortisol between the groups. Salivary cortisol was not higher in therapeutic riding, when compared to recreational riding or rest, and the hypothesis was not supported.

Whether or not therapeutic riding with disabled riders resulted in increased stress to the horse when compared to recreational riding by healthy individuals with no previous riding experience has also been investigated (Fazio, 2013). To assess equine stress the hypothalamic pituitary axis (HPA) was monitored by measuring beta-endorphin, ACTH, and cortisol. The results suggest that the HPA in therapeutic riding horses is less responsive to disabled riders than recreational riders. One interpretation of these results is that the horses have the ability to evaluate the needs of the rider and perform their job. It could also be argued that the disabled riders made fewer demands on the horse to perform.

Another study compared the responses to acute, novel stimuli (restraint by covering the head for an hour and to a startle stimulus, shaking a garland) of therapeutic riding horses and jumping horses (Minero, 2006). They measured heart rate (HR; as an assessment of stress), heart rate variability (HRV; as an assessment of autonomic nervous system activity), and equine behavior. Basal HR of therapeutic riding horses was greater than jumping horses, likely due to the better physical condition of the jumping horses. Both groups of horses reacted to novel stimuli, and therapeutic riding horses did not react less than jumping horses. The authors suggest that this should be considered in therapeutic riding programs. Another interpretation is that TR horses should be exposed to as many different situations and stimuli as possible so that they are comfortable in unusual and unexpected situations. This type of exposure would result in decreased risk of injury to disabled individuals in a TR program. Heart rate variability has been used to assess acute and chronic stress. One group of investigators used Holter monitors to measure HRV in nine horses (15.9 +/- 7.7 yrs.) actively working in an equine-assisted activities setting (Gehrke, 2011). Recordings were taken with horses in a two-acre pasture. When compared to previous studies of two-year old Thoroughbreds, diurnal and nocturnal high frequency (as an assessment of parasympathetic nervous system activity) and low frequency (as an assessment of sympathetic nervous system activity) powers were not different in the horses in this study. Although it has been suggest that comparison of HRV parameters between studies be done with caution (Stucke et al., 2015), due to technical inconsistencies, the difference may be due to age, breed, experience, environment, or nutrition.

A study published in 2017 evaluated equine behavior, based on our ethogram (Kaiser et al., 2006a), and physiologic measurements of stress (cortisol, ACTH, glucose) in horses working with veterans with post-traumatic stress disorder (PTSD) (Johnson et al., 2017). The comparison group, at a different time point, was experienced riders. Although physiologic and behavioral patterns varied, these authors also concluded that TR was not stressful to the horse in this study.

Peer reviewed studies using a variety of methods to assess stress in horses involved in therapeutic riding suggest that the activity is not inherently aversive or stressful to the horse. One could argue that horses in a TR program have coped with their condition by developing learned helplessness (Hall et al., 2008). To rule out learned helplessness, we observed the horses in our study in a pasture setting with conspecifics (other horses) and in traditional lessons. In these situations, the horses in our therapeutic riding study expressed typical horse behaviors, including bite threats, kick threats, ears pinned back, and tail lashing. These behaviors were not observed in the TR setting. Similarly, in our previous study, horses at a horse show exhibited typical horse behaviors that were not seen in the TR setting (Kaiser et al. 2006). The evidence of normal horse behaviors at pasture or in traditional lessons suggests these horses were capable of excellent calm behavior when "doing their job," and were not displaying learned helplessness.

Areas of high pressure underneath adaptive devices may be uncomfortable or painful for the horse and may lead to stress behaviors. Direct pressure measurements beneath each device were taken to evaluate the magnitude of pressure being experienced by horses for each device. The highest pressures were noted when using the BR, and the pressure measurements for the ES and IS devices are of similar magnitude. None of the pressure measurements are alarming when compared to able-bodied riders on a conventional or treeless saddle (Belock et al., 2012).

Various aspects of horse behavior, temperament and personality have been studied (Houpt et al., 2000; McDonnell, 2003; Waring, 2003). However, equine behavior while being ridden has infrequently been examined (Odberg, 1987; Rivera et al., 2002; Weeks & Beck, 1996) and stress behaviors of horses while being ridden in a therapeutic riding setting have received little attention (De Santis et al., 2017; Johnson et al., 2017; Kaiser et al., 2006b; McKinney et al., 2015; Kaiser et al., 2006b).

A study conducted in 1999 concluded: "it is very difficult to objectively determine the suitability of horses for therapeutic riding programs regarding their temperament and reactivity, probably because other traits are considered important" (Anderson et al., 1999). Interestingly, since that time, the number of programs offering therapeutic riding and other equine associated activities have increased, yet there is no consistent method assessing the welfare of the horse in a therapeutic setting (De Santis et al., 2017). Clearly, each center is different, and it is important for the instructors to understand not only the needs of the client, but also the needs of the horse.

The decision of which adaptive device to use is based on the needs of the rider. However, when several adaptive devices may equally benefit the rider, the amount of exertion required from volunteer assistants should be considered. When riders with limited core strength sit in an English saddle, they often need considerable physical support from side walkers, one on each side of the horse. When riders are in need of a backrider, the backrider puts forth considerable exertion and may need an additional side walker. This study shows that assistant exertion is less with the IS than other adaptive devices tested (Figure 4).

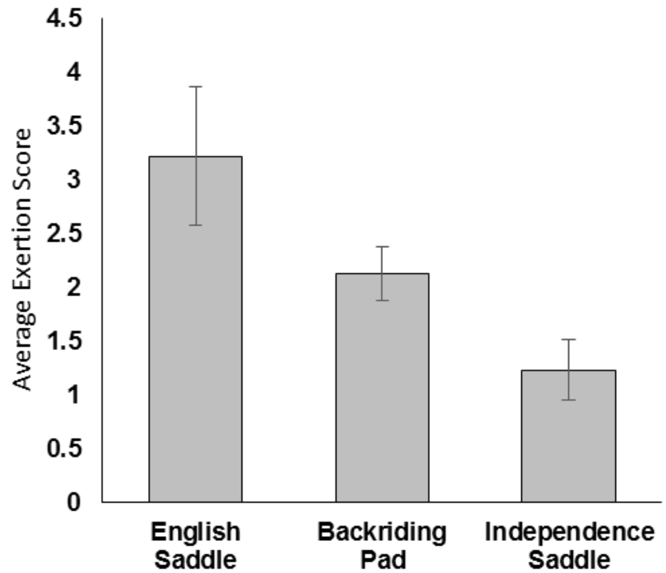

Figure 4: Average exertion score for assistants during use of the English saddle (ES), back riding (BP), and the Independence saddle (IS). Exertion was assessed three different conditions for approximately one minute every five minutes during therapeutic riding lesson protocol (ES, n= 7; BP, n= 4; IS, n=7). Exertion scores while using the IS were significantly lower when compared to ES or BP. The effect of device type on overall exertion scores was significant (P=0.0025). Error bars represent standard error of the mean (SEM).

With the changing societal values regarding the role of animals, it would behoove programs to objectively assess and monitor the welfare of the horses in their equine assisted activities and therapies programs. Further, the Animal Welfare Act (Public Law 89-544, 1966), which “requires that minimum standards of care and treatment be provided for certain animals bred for commercial sale, used in research, transported commercially, or exhibited to the public”, and the Professional Animal Auditor Animal Certification Program (https://animalauditor.org/index.php), which “promotes the humane treatment of animals through education and certification of animal auditors,” could serve as templates to develop scientific criteria to assess the welfare of horses involved in therapeutic riding. Audits designed to promote continuous improvement in therapeutic riding and hippotherapy programs would likely improve the welfare of the horse.

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